Broadkill River
Flood Plain Management Study

Sussex County, Delaware

Dover
Delaware

May 1985

Preface

The Soil Conservation Service, U.S. Department of Agriculture, prepared the information in this flood plain management study. The Delaware Department of Natural Resources and Environmental Control and the Sussex Conservation District cooperated in the report.

The study was conducted by the Tri-State Water Resources Planning Staff of the Soil Conservation Service under the direction of Donald McArthur and Bobbye Jack Jones, State Conservationists, and under the supervision of Michael Kolman, Staff Leader. This report was prepared by Bruce Kirschner, Mark Gates, and Peter Saunders of the Tri-State Staff. Assistance was provided by Mr. Krishna Patel of the Department of Natural Resources and Environmental Control and Richard Bennett, Soil Conservation Service District Conservationist for Sussex County, Delaware.

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Introduction

The purpose of this flood plain management study is to define the hazard of dam failure within the Broadkill River Watershed and to consider various alternatives for improving flood plain management. Local officials will use this report as a guide in improving the existing flood plain management program.

The Sussex Conservation District and the Delaware Department of Natural Resources and Environmental Control requested the Soil Conservation Service (SCS) to conduct this study. SCS prepared a plan of work describing the study area, location, scope, responsibilities, estimated costs, funding arrangements, and tentative schedules. This plan of work was reviewed by the District and Department of Natural Resources and Environmental Control and approved on October 31, 1983.

The Soil Conservation Service, U.S. Department of Agriculture, participated in this study under the following authorities:

Section 6, Public Law 83-566, as amended.

Federal Level Recommendation 3, A Unified National Program for Flood Plain Management, Water Resources Council, September 1979

Executive Order 11988, January 25, 1978

U.S. Department of Agriculture Secretary's Memorandum 1606 and 1607, November 7, 1966

Joint Coordination Agreement, between Delaware Department of Natural Resources and Environmental Control and the Soil Conservation Service dated November 1982

FLOOD PLAIN MANAGEMENT STUDY

BROADKILL RIVER

SUSSEX COUNTY, DELAWARE

Study Area Description

The Broadkill River basin occupies about 110 square miles of eastern Sussex County and drains to Delaware Bay at Roosevelt Inlet through the Lewes and Rehoboth Canal. The river is formed by the confluence of Pemberton and Ingram Branches at Wagamons Pond in West Milton, below which it is navigable to Delaware Bay. As the Broadkill flows eastward from Milton, Beaverdam Creek joins it from the south and Primehook Creek joins it from the north through a drainage ditch that was part of mosquito control project. The former Delaware Bay outlets of Primehook Creek and Broadkill River have been blocked for some time by beach erosion and construction of the Lewes and Rehoboth Canal. Old Mill and Canary Creeks are the principal tributaries to the lower tidal reach of the Broadkill. At one time the generally marshy area landward from Cape Henlopen was drained by Lewes Creek northward to Delaware Bay. The Lewes and Rehoboth Canal was constructed partly along this stream course, however, and the flow from the adjacent marshes and glades now may be transported north to Delaware Bay or south to Rehoboth Bay depending upon tide, tide differential, and channel condition.1/

The waterways were once used considerably for milling and shipment of grain. In recent years, however, production and processing of poultry and vegetables have dominated the economy of the area.

1/ William C. Rasmussen et al, "Water Resources of Sussex County, Delaware," Bulletin No. 8, Delaware Geological Survey, Newark, Delaware, 1960.

Five food processing plants operate within the watershed and seven livestock feedlots contain between 8,000 and 12,000 beef animals. Timber management is important in the upper reaches of the watershed. Clear-cutting of hardwood stands and conversion to loblolly pine plantations for local pulp markets is a common practice. Oystering has developed in the lower reaches of the Broadkill River.

Lewes-Rehoboth Beach communities are expanding into lower portions of the watershed along the Route 14 corridor.

The Broadkill River is a subbasin of the Delaware River which is in the Mid-Atlantic Region as designated by the Water Resources Council. The USGS Hydrologic Unit code number in the area is 02040207.

The watershed is in the Major Land Resource Area designated as Mid-Atlantic Coastal Plain (153C). The predominant soil associations are Evesboro-Rumford in the upper end of the watershed, Sassafras-Fallsington in the middle and Tidal marsh at the lower end. Elevations range from sea level at Roosevelt Inlet to about 50 feet along the western watershed divide.

Normal annual precipitation is 45.7 inches. Average January temperature is 34.4 degrees F and the average for July is 76.3 degrees F. Average growing season is 192 days.

Natural Values

Land Use

Cropland and woodland are the principal land uses in Broadkill River watershed (Table 1). They comprise 77 percent of the watershed. Natural areas, primarily tidal marsh in the coastal region, make up 15 percent of the land area. Residential land is also significant at about 6 percent of the total. Remaining land uses are community services land, commercial and industrial land, water, and other land which is livestock feedlots in the southeastern portion of the Broadkill area. Prime farmland makes up 19,300 acres of non-urban land in Broadkill River watershed. Prime farmland soils are distributed throughout the watershed. They are intermixed with land too wet or too droughty or too steep to classify as prime. Residential development from the expanding Lewes-Rehoboth Beach resort area is encroaching on prime farmland in the lower Broadkill River watershed.

Table 1

PRESENT LAND USE IN BROADKILL RIVER WATERSHED

Land Use	Acres	Percent of Total
Cropland	28,230	42
Woodland	23,275	35
Residential Land	3,980	6
Community Services Land	360	--1/
Commercial/Industrial Land	210	--1/
Natural Areas	9,780	15
Other Land - Livestock Feedlots	735	1
Water	415	1
TOTAL	66,985	100

1/ less than 1%

Note: Community services land includes schools (buildings, grounds, parking), airports, University of Delaware Marine Studies Campus, etc.

Natural areas include swamps and marshes.

Transportation services land is distributed throughout other land uses.

Water Resources

Broad, vegetated, natural flood plains moderate flooding. They spread floodwaters, reduce velocities, and lower flood peaks. A part of the flood waters are trapped and held back as they overflow the stream channel onto the

flood plain. Floodwaters temporarily refill wetlands, and depressions. Trees and other vegetation retard flows. This process, common to undisturbed flood plains, reduces the severity of downstream flooding.[2/] Within the immediate flood hazard area studied, remnants of an effective flood plain remain in the forested wetland between Diamond and Wagmons Ponds.

The railroad crossing in this area, however, could create an unstable debris dam against the trestle in the event of failure of Diamond Pond dam, compounding downstream flooding problems.

2/ Owen, H. James and Wall, Glenn, R., Principals, Flood Loss Reduction Associates, "Floodplain Management Handbook," United States Water Resouces Council, September 1981.

Previous development on the flood plain restricts flood flows. The Milton business district including Union, Magnolia, and Front Streets encroach on the flood plain. The Union Street crossing is especially restrictive forcing flood flows to spread through the community.

The current sewage treatment plant expansion may contribute a slight negative effect to flood plain values, due to encroachment.

Positive impacts of the town of Milton on the flood plain include the establishment of auto parking areas off Magnolia and Front Streets and development of a community park off Chandler Street.

Floodwaters can spread in these areas and cause little damage.

Red Mill Pond is used for primary or contact recreation (swimming). The pond's aesthetic qualities draw residential development to its shores and drainage area. Waples Branch, between Diamond and Wagamons Ponds, contains a build-up of floating organic debris. Round Pole Branch at Atlantic Street floats orange organic solids and foam.

Downstream portions of the Broadkill River are subject to low dissolved oxygen levels and elevated fecal coliform levels.[3/] These levels adversely affect fish and wildlife habitat values. The 1984 Delaware Water Quality Inventory rated the Broadkill medium and high for degree of use impairment. The report notes coliform contamination and eutrophication in Diamond and Wagamons Ponds.[4/]

Oystermen are required to transplant oysters from the lower Broadkill to the Delaware Bay for flushing prior to harvesting.

Potential sources of water quality degradation in Broadkill River Watershed include:

a) Livestock waste--livestock operatons are present in the watershed as

3/ Delaware Department of Natural Resources and Environmental Control, "1982 Delaware Water Quality Inventory Volume III," Dover, Delaware, July 1983.

4/ Delaware Department of Natural Resources and Environmental Control, "1984 Delaware Water Quality Inventory Volume 1: Executive Summary," July 1984.

follows:

3 dairy
2 beef
3 swine
28 poultry

One beef operation has housed up to 8,000 to 12,000 animals on seven feedlots in the watershed. It now has 4,000 to 5,000 animals.

b) In-ground domestic sewage disposal - except in the immediate Lewes area, new residential development depends on in-ground sewage disposal.

c) Food processing wastes - five food processing plants discharge about 3 million gallons of variably treated wastewater daily to the Broadkill River and its tributaries. Chlorination is standard procedure in treating these discharges.5/

d) Milton municipal wastewater treatment facility - presently being upgraded from primary treatment.

5/ Wastewater discharge records, Delaware Department of Natural Resources and Environmental Control, 1984.

Natural Areas

There are a variety of habitats within the general study area, ranging from forested wetlands to a washover barrier on the Delaware Bay, providing outstanding natural areas. One bog near Waples Pond contains northern pitcher plants. Beach Plum Island near Roosevelt Inlet is one of the most undeveloped beaches on the lower portion of the Delaware Bay. Adjacent Canary Creek and Old Mill Creek Marshes are excellent examples of cordgrass communities. The Prime Hook National Wildlife Refuge also lies within the study area. Although some of the refuge has been altered for increased waterfowl or wildlife production portions of unaltered swamp and tidal marsh still remain.

Both the U.S. Fish and Wildlife Service and the Delaware Department of Natural Resources have completed wetlands inventory maps for the area.

Delaware naturalist, Lorraine Fleming, notes several important natural areas in her 1978 monograph.6/ Primehook Creek is an outstanding fish and wildlife area with recreational and educational opportunities. Sowbridge Branch above Waples Pond is an ecologically diverse area containing rare plants. Beach Plum Island represents the only relatively unaltered expanse of beach in lower Delaware Bay. Canary and Old Mill Creek (also known as Red Mill Creek) Marshes have undergone extensive study by the University of Delaware College of Marine Studies.

6/ Fleming, Lorraine M., "Delaware's Outstanding Natural Areas and Their Preservation," Delaware Nature Education Society, 1978.

Cultural Resources

The following locations in Broadkill River Watershed are listed in the National Register of Historic Places:

Governor Ponder House

Draper-Adkins House

Hazzard House

Chipman House

Robinson House

Norwood House

Fisher (Joshua) House

Pagan Creek Dike

Milton Historic District

The lower Broadkill River is known to hold early landing sites for shipping.

Flood Problems

The potential for river or tidal flooding has been addressed in Flood Insurance Studies. This study analyzes the possibility of dam failure within the Broadkill River. The dams within the watershed are:

Impoundment	Area (Acres)	Year	Height (Ft.)
Diamond Pond Dam	24.2	NA	12
Red Mill Pond Dam	178.5	1925	11
Wagamons Pond Dam	50	1815	10
Reynolds Pond Dam	38.2	1915	11
Waples Pond Dam	55.1	NA	8

One element to consider in dam safety is the potential for property damage and loss of life. Reynolds Pond and Waples Pond were not analyzed because of a low potential for property damage and almost no potential for loss of life. Red Mill Pond has a low to moderate potential for property damage and loss of life. Hydraulic and hydrologic analyses of the structure indicates that it is adequately designed and is in little danger of failing due to flood flows. However, this is not the case for Wagamons Pond and Diamond Pond.

Wagamons Pond is located on the Broadkill River at the junction of Pemberton Branch and Ingram Branch. It is immediately upstream of the Town of Milton. In December 1978, the dam was inspected under the Corps of Engineers National Dam Safety Program. The results of that inspection are shown in figure 1. By 1984, very few of the problems cited had been fixed.

UNSAFE DAM
NATIONAL PROGRAM OF INSPECTION OF DAMS

a. NAME: Wagamons Pond Dam

b. ID NO.: DE00061

c. LOCATION State: Delaware County: Sussex
River or Stream: Broadkill River
Nearest D/D City or Town: Milton, Delaware

d. HEIGHT: 10 feet

e. MAXIMUM IMPOUNDMENT CAPACITY: Inventory indicates 69 ac. ft. Visual inspection indicates far more. Capacity being verified.

f. TYPE: Earth with Concrete Overflow Structure

g. OWNER: New Dimensions Inc. of Delaware - Relators
P.O. Box 412, Lewes, DE 19958

h. DATE GOVERNOR NOTIFIED OF UNSAFE CONDITIONS: See Item K.

i. CONDITION OF DAM RESULTING IN UNSAFE ASSESSMENT
1) Deteriorated downstream concrete stop log guides.
2) Sinkhole in downstream slope adjacent to overflow structure.

l. URGENCY CATEGORY: UNSAFE - Non-Emergency

j. DESCRIPTION OF DANGER INVOLVED: If d.s. stop log guides fail, a 7-foot wide breach could occur. A commercial building located several hundred ft. downstream could possibly be knocked off its pile supports by debris laden waters. This condition would only occur at low. (D.S. area is tidal.)

m. EMERGENCY ACTIONS TAKEN:
State Highway Dept. notified day of inspection, 8 Dec 1978 of sinkhole. Highway Dept. stated they fill sinkhole immediately and keep watch on sinkhole area.

k. RECOMMENDATIONS GIVEN TO GOVERNOR:
Letter being prepared to Governor stating full problem with possible courses of remedial action. Governor's representative informed of situation by telephone on 12 December 1978.

n. REMEDIAL ACTIONS TAKEN:
Governor's representative will notify owner to insert new upstream timber stop logs. The upstream stop logs are presently non-functional. This action will relieve pressure on downstream stop log guides.

o. REMARKS:
As additional actions and information becomes available, this report will be updated.

W.H. ZINK
Coordinator, Dam Inspection Program
U.S.A.E.D., Philadelphia
15 December 1978

Figure 1. Inspection Report on Wagamons Pond

A portion of the road over the dam acts as an emergency spillway. When flow occurs in this emergency spillway, there is an increased chance of failure due to erosion of the embankment. Flood routings indicate that water will flow in the emergency spillway three years in ten on the average. Generalized flow over the entire roadway could cause failure of the structure. This condition will occur three years in 50 on the average.

Diamond Pond is located about 4000 feet upstream of Wagamons Pond on Ingram Branch. This structure has not been inspected under the National Dam Safety Program. However, it is similar in design and age to Wagamons Pond, and should be scheduled for inspection. Flood routings for Diamond Pond indicate that water will flow in the emergency spillway three years in 20 on the average. Because of a smaller emergency spillway capacity, the probability of generalized flow is similar to Wagamons Pond; that is, three years in 50 on the average. Failure of Diamond Pond would greatly increase the chances of failure of Wagamons Pond under any conditions. This would result in extensive damages in Milton. There is no way to predict if, when, and how a dam will fail. However, the previously described conditions seemed to be reasonable scenarios to evaluate the effects of a possible dam failure.

Flood flows downstream of a possible dam failure were analyzed with breach routings. The results of this analysis are shown as follows:

Peak Discharges (Q) for Various Conditions

Condition	Scenario	Water Surface Elevation at Wagamons Pond	Volume (acre-ft)	Peak Q Wagamons Pond	Peak Q Front St.
No failure	A	6.6	150	0	0
	B	8.6	275	269	269
	C	10.0	386	936	936
Wagamons fails	A	6.6	150	1470	786
	B	8.6	275	2700	2000
	C	10.0	386	3710	2670
Wagamons & Diamond fail	A	6.5	225	1470	1190
	B	8.6	445	2700	2140
	C	10.0	776	3710	2990

In this table, Scenario A represents a normal flow or non-flood situation. This is indication of dam failure occurring when there is no flooding or of a delayed failure after generalized flow over the roadway. B represents flow beginning in the emergency spillway. C represents generalized flow over the roadway. All of these figures were computed assuming low tide conditions. As shown in the Corps report (see figure 1, item j), maximum damage would occur at low tide. This damage would be due to a wave of water proceeding downsteam. The damage simply due to a depth of water is generally the most important factor in flooding. In this situation, this type of damage has no significance. In fact, the actual depth of water would be less than 100 year tidal elevation which is about 9 feet NGVD.

Existing Flood Plain Management

Sussex County has participated in the National Flood Insurance program since October 6, 1976. The Town of Milton has participated since August 1, 1978. They are both in the regular program. This means that they have passed the appropriate zoning ordinances to limit development within the one percent (100-year) flood plain. Within Delaware there are no State laws that add requirements to the Federal program. The Federal program is administered by the Federal Emergency Management Agency (FEMA). In communities participating in the FEMA program, all buildings and mobile homes are eligible for subsidized flood insurance coverage.

Alternatives for Flood Plain Management

Present Trends

During the next 20 years 4475 acres of cropland and woodland are expected to be converted to urban land uses in the Broadkill River Watershed (Table 2). Three thousand two hundred acres of this land is prime farmland. Most of the development will occur as an expansion of the Lewes-Rehoboth Beach resort area along Route 14 north to the crossing of the Broadkill River. Some homes for seasonal usage may develop north of Broadkill River. Urban growth in other parts of the watershed is expected to take place in response to local building needs only. According to Sussex County planning officials, Milton may grow slightly faster than other small communities.

Table 2

FUTURE LAND USE IN BROADKILL RIVER WATERSHED

Land Use	Acres	Percent of Total
Cropland	24,800	37
Woodland	22,230	33
Residential Land	8,255	12
Community Services Land	440	1
Commercial/Industrial Land	330	—1/
Natural Areas	9,780	15
Other Land - Livestock Feedlots	735	1
Water	415	1
TOTAL	66,985	100

1/ less than 1%

Note: Future conditions are based on a 20 year projection by the Sussex County Planning and Zoning Department, March 1984.

Community services land includes schools (buildings, grounds, parking), airports, University of Delaware Marine Studies Campus, etc.

Natural areas include swamps and marshes.

Transportation services land is distributed throughout other land uses.

Land Treatment

Increased emphasis on planning and application of waste management systems and their component practices can reduce potential water quality degradation from livestock sources. Assistance can also be extended to food processors with waste management problems as appropriate. Currently, a waste management plan is being developed on the seven large feedlots.

Although insufficiently documented, regular farming practices, including routine fertilizer applications, may pose a threat to groundwater quality in the moderately coarse-textured soils of the Delaware Peninsula, generally. Increased emphasis on conservation cropping systems and irrigation water management through the Sussex Conservation District program may reduce this threat. These practices can help farmers satisfy crop needs while avoiding excessive rates of application.

Certain needed land treatment practices may be eligible for cost sharing through USDA-Agricultural Stabilization and Conservation Service (ASCS) or the Delaware State Conservation Cost Sharing program administered by the Department of Natural Resources and Environmental Control Division of Soil and Water Conservation. USDA-Farmers Home Administration (FmHA) can provide loan assistance for conservation measures.

Preservation and/or Restoration of Natural Values

Agricultural sales contributed nearly $270 million to the economy of Sussex County in 1982.7/ Broadkill Watershed, like Sussex County generally, has significant prime farmland soils. With strong competing urban growth apparent, county officials may want to more fully assess relative values of agricultural lands, including forests, countywide, and consider enactment of farmland preservation policies to direct urban growth toward areas with the least adverse impacts on the agricultural sector. The national agricultural Land Evaluation and Site Assessment (LESA) system may provide a vehicle for making this assessment. LESA is designed to determine the quality of land for agricultural uses, including cropland and forest land and to assess sites or land areas for their agricultural economic viability. The Sussex Conservation District can provide assistance in the application of LESA.

The Land Evaluation part of LESA has already been completed by SCS. The State Department of Agriculture is working on the Site Assessment portion using public participation (committees on the county level).

7/ U.S. Department of Commerce, Bureau of Census, "1982 Census of Agriculture."

Upland stream corridors in Broadkill River Watershed offer an opportunity to maintain multiple use environmental corridors. In flood prone areas protection from further development will retain full remaining valley areas to spread floodwaters to minimize flood velocities and peaks. Protection will also:

1. Maintain flow retarding vegetation.
2. Reduce the amount of property susceptible to flood damage.
3. Retain important wildlife habitat.
4. Contribute to scenic natural beauty of the area. Near Milton the stream corridor downstream from Diamond Pond and the undeveloped, wooded east bank of Diamond Pond are exeptionally visually pleasing.
5. Provide passive recreation
6. Help protect cultural resources, especially potentially important archeological sites.

Tidal areas are protected by the permitting process of section 404 of the Rural Clean Waters Act of 1972 administered by the U.S. Army, Corps of Engineers.

Nonstructural Measures

Flood proofing of structures in the flood plain would help reduce damages due to high water level. These measures should be considered for reducing damages. Flood proofing will not be of any help in case of a rapid dam failure.

Flood warning is practical and desirable. A siren activated when water begins flowing over the road could provide the warning necessary to save lives. A simple warning system would cost about $3000.

Relocation of properties downstream of Wagamons Pond would reduce flood damages and potential for loss of life. This alternative is probably not possible at the local level without Federal or State aid.

Zoning and land use regulation can prevent new development in the flood plain but does nothing for the existing properties.

Draining Wagamons Pond or Diamond Pond would reduce chance of failure slightly. These are shallow ponds with litle storage capacity. A storm would quickly fill up the ponds and the effect of draining then would be minor.

Structural Measures

Rebuilding the dam is probably the most desirable option locally. However, no one has been able to find sufficient funding for this in the past several

years, despite intensive effort. Rebuilding the dam is probably not an attainable alternative without direct state involvement.

Replacing the current principal spillway with a new bridge and essentially removing the dam could drain the pond and provide enough area to pass flood flows without breaching the roadway. This would solve the problem of possible failure of Wagamons Pond Dam. This would increase flood levels downstream slightly because the current dam does provide some flood protection. This is also true for the alternative of removing Diamond Pond Dam either independently or in conjunction with the removal of Wagamons Pond Dam.

It is possible to prevent the dam and roadway from washing away by protecting the embankment with riprap or other material. This could cost almost as much as replacing the dam.

Combination of Alternatives

There are no combinations of alternative measures that provide significantly greater benefits than individual measures.

Glossary of Terms

- backwater - High water caused by downstream obstruction or by high stage on a downstream lake or bay.
- breach routing - computation of the changes in flow of the water resulting from a dam failure as the water moves downstream.
- cfs - Cubic feet per second - a unit of discharge that is equal to the flow of one cubic foot of fluid past a given point per second.
- cross section - Shape and dimensions of a channel and valley perpendicular to the line of flow.
- flood - An overflow of lands not normally covered by water; a temporary increase in streamflow or stage; or the discharge causing the overflow or temporary increase.
- flood peak or flood discharge - Highest discharge attained during a flood.
- flood plain or flood prone area - Lands adjoining a stream or other body of water which have been or may be covered with water.
- flood profile or profile - A plotted or imaginary line defining the highest water surface elevations along a stream during a particular flood.
- flood-prone area - See flood plain.
- flood routing - Computation of the changes in the rise and fall in streamflow as a flood moves downstream. The results provide hydrographs of discharge versus time at given points on the stream.
- hydrograph - A curve showing the rise and fall of flood discharge with respect to time at a specific location on the stream.
- land use - Classification of type of vegetation or other surface cover conditions on a watershed; used (with a similar classification of soils) to indicate the volume and rate of flood runoff.

- NGVD - National Geodetic Vertical Datum of 1929 - used as the standard reference for mean sea level.
- peak discharge or flood peak - The highest rate of runoff (discharge) attained during a flood.
- prime farmland - Land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops and is also available for these uses.
- profile - See flood profile.
- runoff - That portion of the total storm rainfall that flows across the ground or other surface and contributes to the flood discharge.
- watershed - A drainage area which collects and transmits runoff to a given point.

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Appendix 1

Dealing with Floods

This flood plain management study is an aid to persons living in flood prone areas. If your home is within the flood plain, the following information should serve as a guide for dealing with floods.

Being well informed is your best protection. It is extremely important to know where to go in the event of a flood. Remember that roads are often built within valleys where flood waters are most likely to go. You should reach higher ground, and it may be easier and safer to do this on foot rather than by car.

The major causes of floods are melting snows and rainfall. Listen to weather reports and be aware of the chance of flooding. Never ignore a flood warning. Listen for emergency instructions and follow instructions given.

If it is necessary for you to evacuate your home, do so quickly and cautiously. Follow evacuation instructions that are given. Do not try to take all of your belongings with you. Take necessary personal items such as eyeglasses or medicines, flashlights, a small supply of canned food and several blankets.

If you are traveling by car, you may encounter these hazards:

washed-out road or bridge

undermined roadway

downed power lines

floating debris

Watch for these hazards carefully.

If it is not necessary to evacuate you home, there are precautions you should proceed with.

Fill large containers with water, and after doing so, shut off the main water valve to protect the clean water already in your water system. Be certain to shut off your water heater since no water will be going into it.

As long as electric service is available, it may be used safely unless the main circuits are flooded. In such a case, you will reduce the risk of electrical shocks and short circuits if you turn the power off. Do not touch the switch if you are wet or standing in water. Unless you detect a gas leak, you may continue to use gas systems.

Be aware that floods often produce fire hazards. Watch for broken or leaking gas or oil lines, flooded electrical circuits, flooded furnaces and other appliances, and inflammable or explosive materials which may come from upstream.

Anchor or move inside any belongings such as trashcans, toys, lawnmowers, etc. They may become hazards to people downstream if they are washed away.

Move livestock to high, open ground and if possible keep them from drinking flood water or eating food soaked with flood water.

The following items could help improve your chances of survival if a flood occurs:

- portable radio and spare batteries
- first aid kit
- flashlights and spare batteries
- foods which require little or no cooking and no refrigeration
- blankets
- rope
- hand tools
- drinking water

Precautions taken to reduce losses from flooding are called flood proofing.

The basement walls of your home are probably not built to withstand the additional pressures of water soaked soils. You may have less damage if you allow flood waters to come in. When you receive a flood warning, remove articles from the basement and open a basement window. Fuse boxes and other equipment should not be located in the basement.

Flood proofing for homes with adequately reinforced basement walls could include: sealing cracks in walls and floors with hydraulic cement, installation of a sump pump with a reliable power source, placing heavy screens over windows to prevent breakage from floating objects, and placing valves on drain lines to prevent backup of water.

It is important to remember that flood proofing can help reduce damages; it does not make it safe to remain in your home during a flood.

After a flood, reenter buildings with caution. Watch for fire hazards and falling debris. Do not use appliances until they have been checked for damage. Do not use any food or water which may be contaminated.

Normal home insurance does not cover flooding. Ask your insurance agent about federally subsidized flood insurance. Not all agents handle flood insurance, and you may have to contact several of them.

Many people are hurt or killed during or after a flood by their own carelessness. Know beforehand what to do if a flood occurs. Your local Civil Defense Agency can help you with any questions you may have.

Appendix 2

Conversion Factors

U.S. Customary to Metric (SI) Units of Measurement

U.S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
acres	0.4047	hectares
bushels	35.24	liters
feet	0.3048	meters
cubic feet	0.02832	cubic meters
gallons per minute	0.003785	cubic meters per second
million gallons per day	0.0438	cubic meters per second
inches	25.4	millimeters
miles	1.609	kilometers
square miles	2.589	square kilometers
pounds	0.454	kilograms
tons	0.908	metric tons
tons per acre	2.244	metric tons

To obtains Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula:

$$C = (5/9)(F - 32)$$

Appendix 3

Technical Appendix

Cross section data and the hydraulic characteristics of the dams were taken from the Corps of Engineers Phase 1 Inspection Report. Elevations are referenced to National Geodetic Vertical Datum (NGVD) of 1929.

The peak discharge-frequency relations of stream gages in the vicinity were determined by the USGS WATSTORE program. This program uses a log-Pearson Type III analysis as recommended by the Water Resources Council. These discharges were correlated with TR-20 routings within the watersheds and used to detrmine peak discharge-frequency relations entering the ponds.

The dam breach routing procedure described in Technical Release No. 66 was used for this study. It is common to use the flood associated with the probable maximum precipitation for dam breach routing. The TR-20 routings indicated that the dam would overtop and probably fail at a much more frequent storm. Therefore, smaller and more frequent storms were used for the breach routings.

Copies of the computer output generated during the analyses are available from:

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